

**Center for Independent Experts (CIE)  
Independent Peer Review Report**

**STAR Panel Review of 2020-2021 Pacific  
Sardine Stock Assessment**

**Southwest Fisheries Science Center,  
La Jolla, California, 24-27 February 2020**

**Prepared for the Center for Independent Experts**

**By**

**Dr José A. A. De Oliveira**

**April 2020**



## Executive Summary

A STAR Panel review of the 2020-2021 stock assessment of the northern subpopulation of Pacific sardine (*Sardinops sagax*) was held during 24-27 February 2020 in La Jolla, California. The review activities included reviewing the draft stock assessment and other pertinent information provided in advance of the review meeting, working with the STAT team to ensure input data and assessment models are reviewed as necessary, and recommending alternative methods and/or modifications to proposed methods, as appropriate. This independent peer review report describes the material and methods provided for the review, and focuses on the review activities leading up to the selection of the final base model for the 2020-2021 stock assessment, providing a summary of findings and recommendations.

Review activities focussed primarily on the basic model inputs to more fully understand these, on how to account for the sardine biomass inshore of the acoustic survey area (that included not only of the main survey vessel, but also the sail drone and fishing vessels that supplied acoustic estimates), and on how to deal with the unrealistically high estimates of fishing mortality for the model years for which catch data were not available. The starting point of the review was the proposed base model, which already contained some modifications compared to the ALT model used during 2017-2019 (a new stock synthesis version, updated catches for the Ensenada fishery, updated acoustic trawl survey indices and age compositions, new priors on natural mortality and survey catchability, time-varying fishery selectivity, time varying age 0 selectivity for the acoustic trawl survey, and fixing steepness at a previously estimated 0.27 instead of estimating it). In moving towards a final base model, the poorly-fitted spring acoustic trawl survey age compositions were omitted because they were based on ALKs pooled over years; the value of steepness was fixed and rounded up to 0.3; survey catchability was no longer estimated and instead split into two periods: set equal to 1 prior to 2015 (when the acoustic trawl survey was believed to cover the bulk of sardine biomass), and set equal to 0.733 from 2015 onwards, which was the acoustic trawl survey biomass in 2019 as a proportion of the combined acoustic trawl survey and aerial CCPSS biomass in 2019 (to reflect the increasing proportion of sardine biomass inshore of the acoustic trawl survey since 2015); for the years for which catch data are not available (2020-2021), the fishing mortality was set equal to the immediately preceding season where catch data were available (2019); the recruitment regime parameter was removed from the likelihood (a technical adjustment necessitated by the move to a newer version of stock synthesis).

The Panel concluded that the final base model represented the best available science regarding the current status of the northern subpopulation of Pacific sardine. The CIE reviewer fully supports and endorses the Panel's findings and recommendations, as reflected in the Panel report.

## Background

The review concerns the 2020-2021 stock assessment for the northern subpopulation of Pacific sardine (*Sardinops sagax*). The majority of review material (including the draft assessment report) were made available through the FTP site:

([ftp://ftp.pcouncil.org/pub/2020\\_Sardine\\_STAR\\_panel/](ftp://ftp.pcouncil.org/pub/2020_Sardine_STAR_panel/))

before and during the meeting, as described in Annex 1; however, detailed model outputs (e.g., .sso files) were not made available on this site. The actual STAR Panel review took place at the Southwest Fisheries Science Center in La Jolla, California over 24-27 February 2020. Details of this meeting, including Terms of Reference and Agenda, can be found in Annex 2 and its Appendices, and a list of participants in Annex 3.

The STAR Panel comprised four equal members, two of which were CIE reviewers (see Annex 3). The main responsibilities of the STAR Panel were as follows:

- (a) Review stock assessment data inputs.
- (b) Review the analytical models presented.
- (c) Provide complete STAR Panel reports.

In particular, the STAR Panel are responsible for determining if a stock assessment or technical analysis is sufficiently complete, any decision on this having to be made by Panel consensus.

Along with the entire STAR Panel, the CIE Reviewer's duties included the following:

1. Reviewing the draft stock assessment and other pertinent information (e.g., previous assessments and STAR Panel reports).  
*This was done by reviewing material provided prior to and during the meeting (Annex 1).*
2. Working with STAT Team to ensure assessments are reviewed as needed.  
*A number of requests were made to explore alternative parameterisations and model sensitivities, including alternative weighting and the exclusion of some data (Annex 4).*
3. Documenting meeting discussions.  
*These are reflected in the STAR Panel report and below.*
4. Reviewing summaries of stock status (prepared by STAT Team) for inclusion in the Stock Assessment and Fishery Evaluation (SAFE) document.  
*Summaries were provided during the meeting for the final model (final base model; see Annex 5 for description). Detailed model results were not supplied to reviewers during the meeting, but after the meeting along with further summary plots on request (but not on the ftp site). Easier access to model outputs should be facilitated for future reviews.*
5. Recommending alternative methods and/or modifications of proposed methods, as appropriate, during the STAR Panel meeting.  
*These were reflected in the number of requests the STAR Panel made to the STAT (Annex 4) as well as the research recommendations (see STAR Panel report and below).*
6. The STAR Panel's terms of references concern technical aspects of stock assessment work. The STAR Panel should strive for a risk-neutral approach in its reports and deliberations.  
*The STAR Panel indeed kept to technical aspects of the stock assessment and its input data.*

Following the meeting, a careful review of the STAR Panel report was conducted, and suggestions made for improvements, making sure that all statements and conclusions were backed up and justified by model outputs and results.

## Review activities and findings

The Agenda for the meeting is given in Appendix 3 of Annex 2, with a list of participants in Annex 3, and detailed descriptions with accompanying rationale and outcomes for all review requests provided in Annex 4. This section attempts to summarise these activities and their findings.

### Presentations

Presentations were covered on the first day of the meeting (three in total, uploaded to the ftp site; see Annex 1). The first presentation was led by Peter Kuriyama and covered the input data to the assessment, the proposed base model for the northern subpopulation of sardine (including a “bridging” analysis to investigate changes from the previous model of 2017-2019; see Figure 1), and some sensitivity tests (e.g., Figure 2). The second presentation was led by Juan Zwolinski and covered the acoustic trawl method (ATM) survey (on the vessel Reuben Lasker), including a brief summary of methodology, but focussing on the 2019 survey results, which included near-shore acoustic estimates using two commercial vessels (Lisa Marie and Long Beach Carnage) and a sail drone. The third presentation was led by Kirk Lynn and covered the California Coastal Pelagic Species Survey (CCPSS), which is an aerial survey that has now provided two years of near-shore biomass estimates of sardine that is more-or-less synoptic with the ATM summer surveys in 2017 and 2019. Further presentations were provided following requests and covering issues related to apportioning catch between the northern and southern subpopulations of sardine (Kevin Hill), biomass and variance calculations for the aerial surveys (Emmanis Dorvall and Kirk Lynn), age-determination issues (ageing protocols by Emmanis Dorvall, and modelling of ATM age compositions by Juan Zwolinski), and further model runs and sensitivities (led by Peter Kuriyama).

### Exploring input data

#### *Catch data*

Although the methodology for assigning catches to the appropriate sardine subpopulation (northern or southern) is now well established, there remain uncertainties about this process. In particular, recent (2017-2019) Ensenada landings had to be filtered with VMS data (instead of using landing port alone) in order to exclude sardine caught south of the southern boundary of the habitat model, because a portion of the Ensenada fleet was fishing much further south than its customary fishing grounds. Request 9 compared the resultant adjustment in catches. Furthermore, no age-compositions were available for the Mexican data, and request 10 compared the length compositions from Ensenada with those from southern and central California but found these data to be variable rather than systematically different. Age compositions for incidental catches (INC), largely from the MexCal region, are available from 2015 onwards, and request 1 considered these. A sensitivity run was presented that included these INC data, but results showed their inclusion had little impact (Figure 2b).

Finally, in order to provide a catch forecast, catch assumptions are needed for the years for which there are no catch data, in this case, model years 2019-2 to 2020-2 – for these years, the corresponding seasonal catches for 2018-2 and 2019-1 are used, but this led to unrealistically high estimates of Fishing mortality (first noted with request 18). A sensitivity analysis exploring alternative assumptions about catches for the no catch data years (see request 22c), led to similar results compared to the proposed base model. The decision was therefore taken

to replace the constant catch assumption with a constant F assumption (i.e., assuming constant effort; see request 21).

### ***Fishery age composition data (including weights at age)***

The assessment philosophy was to focus on selecting an approach that made use of the data source considered by the STAT to be the most objective (i.e., the Acoustic Trawl Method (ATM) survey). One way of ensuring this was to give the model as much flexibility as needed (through flexible selectivity curves) to fit the fishery age composition data so that these data have minimal effect on the total likelihood; as a result of this, the fits to the fishery age composition data are very good. Inspection of the fishery weights at age showed odd behaviour, which may have been due to low sample sizes, so plots of sample sizes by age were requested (request 2). The STAT clarified that the numbers in Table 3 of the 2020 stock assessment draft report (Kuriyama *et al.* 2020 in Annex 1) were in fact number of samples (i.e., of ~25 fish each) and not numbers of fish (as stated in the table caption).

### ***Survey age composition data (including weights at age)***

Survey otoliths for the years 2017 and 2018 were re-aged and validated, because the original age reading was found to be unreliable (new age reader with limited experience) (request 6).

Survey selectivity was modelled to be flexible at age 0 and fixed at 1 (full selectivity) for age 1 onwards (although the presentation by Peter Kuriyama, and further sensitivity analyses during the meeting [see below], did explore alternatives). Fits to the survey age compositions were generally poor prior to 2017, which may be linked to low sample sizes (much lower for surveys compared to fishery age compositions). It was not immediately clear from the sample sizes by age (request 2) why the 2017 onwards age compositions were better than those prior to 2017 (and were fit much better by the model), but the reason given was that those prior to 2017 were not only based on small sample sizes, but that these samples were also only based on a few trawl clusters. This was not clear from either the presentations or assessment documentation. Sensitivity runs explored leaving out the pre-2017 survey age compositions (request 19), but this only led to small improvements. The STAT is encouraged to provide more information about the underlying data in the future in their reports to improve understanding and help better interpret model results.

A description of the method used to model survey age-length keys, along with model fitting diagnostics, was provided (request 5). The model used was a cumulative logistic, a framework which provides a stricter structure for conditional age-at-length (compared to the previously-used multinomial approach), and is therefore, arguably, more beneficial for low sample sizes. Although this modelling approach was applied independently each year for summer surveys, it was not possible to do so for spring surveys, and a pooled age-length key was used instead. This led to the spring age-composition data having to be omitted (request 17) because of the biases that result from not accounting for time-varying cohort strength (when pooling across years).

Sensitivity analyses explored alternative, more flexible, formulations of survey selectivity (with the ATM survey age compositions treated as coming from a separate fleet) in order to better fit the ATM survey age compositions (requests 22a and b). For these analyses, just changing the shape of survey selectivity did not lead to a substantial improvement of the fit to the ATM age compositions, but introducing more flexibility (including temporal) in survey selectivity led to substantial improvements in fit, but with unrealistic and difficult-to-justify selection patterns. It should be added here that the fits to the summer 2017-2019 ATM survey

age compositions were reasonable under the survey selection pattern of the final base model (Annex 5).

### *CCPSS aerial surveys*

Aerial California Coastal Pelagic Species Surveys (CCPSS) have the potential of providing biomass estimates of the northern subpopulation of sardine for areas not covered by ATM surveys, if conducted synoptically with the ATM surveys in areas classified as suitable for the northern subpopulation of sardine. CCPSS have been held since 2012, but two recent CCPSS (2017 and 2019) fulfil these criteria. There was much discussion during the meeting about these surveys, and about the non-directed fishery (NDF) and point-set data from a nearshore cooperative survey (NCS) project used to characterise and/or correct the biomass estimates from the CCPSS for systematic bias (requests 7 and 8). Discussion focussed on the calculation of biomass and variance from a two-band, multiple day design, which was corrected during the meeting (requests 11 and 15). Aerial surveys other than the chosen two had indicated that spatial variability could be a proxy for temporal variability, but this was thrown into doubt when focussing on the chosen two years, because biomass seemed to be concentrated in band 1 (closest to shore). I would suggest that more than just two years are needed to confirm biomass is not spread evenly across the bands (and hence that spatial variability cannot be a proxy for temporal variability); nevertheless, the STAR Panel recommended that repeat transects are needed in order to characterise temporal variability.

Point set data (such as from the NCS) are an important component of the CCPSS; they are used to calibrate observer bias, but can also provide the data needed to be able to estimate the selectivity associated with CCPSS biomass estimates, which would be required if it were to be included in an assessment. However, there are several problems with these data for the available aerial surveys: sampling protocols require further development before the data can be used (e.g., using purse seine nets with a mesh size that can catch anchovy effectively, and thus provide unbiased estimates of species composition), most of the point sets are not synoptic with the aerial survey, and the data required for the estimation of selectivity is still lacking. For these reasons, the CCPSS biomass estimates were not included directly in the assessment, but instead used to characterise survey catchability.

A further point made about the CCPSS is that even though they are more like a census of the area covered than a survey, they can only provide a stochastic lower bound on the total biomass in a band, given both the detection probability of a school (poorly understood), and measurement error and bias that arise from the aerial estimation process. Furthermore, even though repeat transects will get at the variability of school size detection, the variability caused by the incomplete detection of schools will likely be overestimated because it will be confounded with the variability caused by fish moving between bands.

### *ATM surveys*

There was a correction of target strength for herring, which then affected the apportionment of back scatter to other species and meant that ATM survey estimates for sardine were revised for several years; this affected all summer surveys between 2012 and 2018. Request 3 asked for a summary of the method for calculating biomass and variance from the ATM surveys.

The ATM surveys had recently undergone a methodology review (Jan/Feb 2018), so the STAR Panel review did not repeat this process; nevertheless, there was an acknowledgment by the Panel that the ATM survey was not covering inshore biomass, even with increased efforts to survey areas (acoustically, with commercial vessels and a sail drone) closer to the coast than



the Reuben Lasker is safely able to survey. This was clear from 2017 and 2019 synoptic CCPSS, which estimated sizeable biomass of sardine (e.g., for 2019, much higher than the acoustic estimates provided by the vessels operating shoreward of the Reuben Lasker: 469 mt [CV=28%] for the latter versus 12279 mt [CV=134%] for the former). The panel was also interested in the extent to which the areas covered by each of the surveys overlapped (request 4), and it appears that there is little overlap between CCPSS (with most of the biomass concentrated in band 1) and the other surveys.

The additional inshore biomass estimated by the CCPSS (not included in the proposed base model) led to concerns about the way the  $Q$  prior was derived, and request 12 asked for a justification for it. In the proposed base model, the  $Q$  prior was very informative (mean 0, standard deviation 0.1 in log-space), and an attempt to make it less informative (standard deviation 0.2) led to high  $Q$  ( $\sim 1.5$ ) and low  $M$  ( $\sim 0.4 \cdot \text{year}^{-1}$ ), so the model was effectively not able to estimate scale. This, together with concerns about the missing inshore biomass, led to the request that  $Q$  be fixed at 1 for the years prior to 2015, and then at 0.733 (based on 2019 ATM and CCPSS estimates:  $\text{ATM}/(\text{CCPSS}+\text{ATM})$ ) from 2015 onwards (when reports of substantial inshore biomass of sardine first emerged)(request 20). Only the 2019 CCPSS data was used for this purpose, because point set NCS data were available that year (but not in 2017), and because the bulk of the schools detected were less than 100 mt, and thus fitted within the adjustment relationship (used to calibrate for observer bias) based on point set NCS data (request 11). A sensitivity test explored sensitivity to changing the year in which  $Q$  changes (one year before and one year after), but the model was insensitive to this (request 22d).

#### ***Data not currently included in the model***

The current assessment does not make use of all available data. Apart from the aerial survey data, the Daily Egg Production Method (DEPM) index, the Total Egg Production index (TEP), and data prior to 2005 are not used. The 2005 starting year for the assessment coincides with the availability of biomass estimates from the ATM survey time series, and exclusion of the DEPM data had a negligible impact on past assessments. Also not used are the juvenile rockfish survey data, which could potentially provide informative data on sardine recruitment (request 13); however, this survey would need to undergo a methodology review before it could be considered for inclusion in the northern subpopulation sardine stock assessment.

#### ***Assessment model runs***

Kuriyama et al. (2020) presents the proposed base run, while the presentation by Peter Kuriyama (see Annex 1) showed additional sensitivity runs (e.g., Figure 2; see also end of Annex 4). During the STAR Panel Review meeting, additional model runs (including further sensitivity runs) were requested and presented (see Annex 4). In Annex 4, Table A4.1 links the requests to model runs (my labelling of model versions), while Table A4.2 describes the difference between the various model versions (my interpretation given information I had, which may be incomplete), from model A (the proposed base run) to model H (the final base run), with additional sensitivities listed after Table A4.2.

An important first step was the comparison between two versions of Stock Synthesis given the same data (Figure 1a), which showed minor differences, followed by an (almost) one-step-at-a-time bridging analysis from model ALT (used in 2017-2019) to the proposed base model (Figure 1b). The models were comparable and robust in the depiction of a strong decline of sardine biomass since the mid-2000s, and low current biomass levels. The addition of the CCPSS estimates for 2017 and 2019 to the ATM estimates (a sensitivity run not supported by



the Panel in the way it was done) showed an almost doubling of current biomass, from 22301 mt to 37276 mt (Figure 2a).

When the panel was inspecting the diagnostic plots for the proposed base run (model A), it became clear that the SR regime parameter (the R1 offset) was not behaving as it should, because it had unexpected influence on the total likelihood (Figure 3); both the Panel and STAT were unclear how this parameter was defined, and additional model runs either did not estimate the parameter (model B1), or removed it from the likelihood by setting the corresponding  $\lambda$  in the likelihood to zero (model B2; request 14). This meant, however, that steepness was no longer estimable (model C1; request 16) and was instead fixed at 0.3 (model C2), close to the value in previous models when it was still estimable.

Regarding steepness, I have reservations about the decision to fix steepness at 0.3:

1. This decision seems somewhat arbitrary, and it was not clear why the proposed base model, after setting  $\lambda=0$  for the R1 offset, was no longer able to estimate it, whereas before (e.g., in the 2017-2019 ALT model), it was able to do so. The STAT should investigate this further to fully understand what is happening. One suggestion is to use the final base model and strip it back to the same data and configuration as in the ALT model, then to check if it can estimate steepness; if not, why not?
2. What about constructing a prior for steepness, or basing a value for steepness on the work of Myers et al. (1999); they derive a median steepness for clupeidae of 0.71 (20<sup>th</sup> and 80<sup>th</sup> percentiles of 0.49 and 0.86, respectively).
3. Would extension of the model back in time to provide further estimates of stock-recruit pairs (so it covers a period of more than just the almost constant decline of the stock since the mid-2000s) help the estimation of steepness? This may help with the estimation of reference points also.

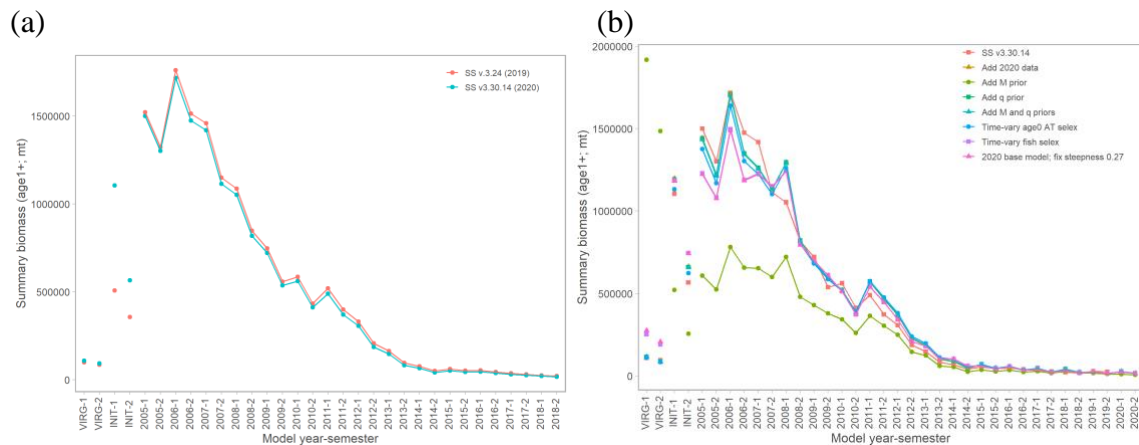


Figure 1. Bridging analysis between (a) SS version 3.24aa (2017-2019) and version 3.30.14 (2020), and (b) the model configuration (ALT) used for 2017-19 and the proposed base model for 2020. [Note: in (b), model “Add M prior” did not converge, and is therefore unreliable.]

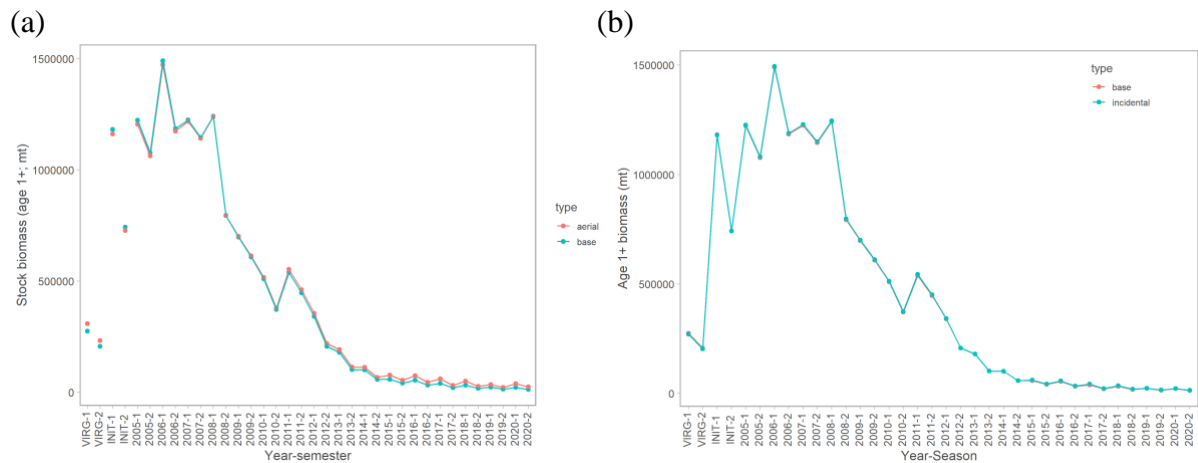


Figure 2. Sensitivity to addition of data for proposed base model: (a) CCPSS aerial survey data (2017 and 2019) (base biomass=22301mt; including aerial=37276mt), and (b) INC (incidental catch) data (base as before; including INC=22996mt). [Note: the first four points in (b) should not be linked with a line – see (a).]

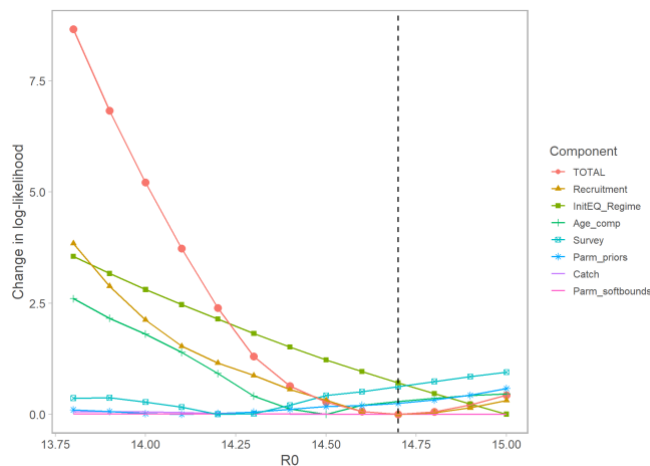


Figure 3. Likelihood profile on  $R_0$  for the proposed base model. [Note the SR Regime parameter (*initEQ\_Regime*) is highly influential, which was not the intention.]

Model D looked at the impact of removing the spring ATM age compositions (request 17), while model E consolidated all accepted decisions to that point ((a) continue to estimate the  $R_1$  offset parameter but setting the corresponding  $\lambda=0$  in the likelihood, (b) fix steepness at 0.3, and (c) remove the spring ATM age compositions; request 18), but it was then first noticed that the fishing mortality for calendar years 2020 and 2021, for which catch assumptions were needed, were unrealistically high. An attempt to remove the pre-2017 ATM age compositions (model F; request 19) improved the fits to the remaining ATM age compositions slightly, but fishing mortalities from 2020 onwards remained unrealistically high. This led to the recommendation to use a constant  $F$  assumption instead of a constant catch assumption for the years with no catch data, which formed part of the final base model.

Model G dealt with the fact that the inshore biomass could no longer be ignored in the face of substantial biomass estimates from the CCPSS, but also that it was not really possible to estimate scale for this assessment (without a highly informative prior on survey  $Q$ ). Because reports of substantial inshore biomass first emerged in 2015, this year was set as a year when  $Q$  changed from 1 prior in 2015 to 0.733 from 2015 onwards (request 20), based on the ATM survey estimate for 2019 as a proportion of the combined ATM survey and CCPSS biomass

estimates for 2019. Model H consolidated all the decisions agreed by the STAR Panel and the STAT to form a final base model, described in Annex 5 (see also request 21).

Two sets of sensitivity runs were conducted for final base model H, one looking at the major sources of unresolved uncertainty (request 22; these relate to improving the fit to the survey age compositions, investigating alternative catch assumptions for the most recent years where catch data are not available, and investigating sensitivity to the timing of the change in Q), and another looking at alternative weighting of the data (request 24; these relate to down-weighting of the ATM survey and Pacific Northwest fishery age compositions, only including survey age compositions from 2017 onwards, and estimating an additional variance parameter for the ATM survey). See Annex 4 for a more detailed description.

Key model results, supplied by the STAT after the STAR Panel Review meeting and on request, are shown in Figures 4-6 (but see also request 23). [These figures did not appear in the STAR Panel Report when I drafted this CIE review report.]

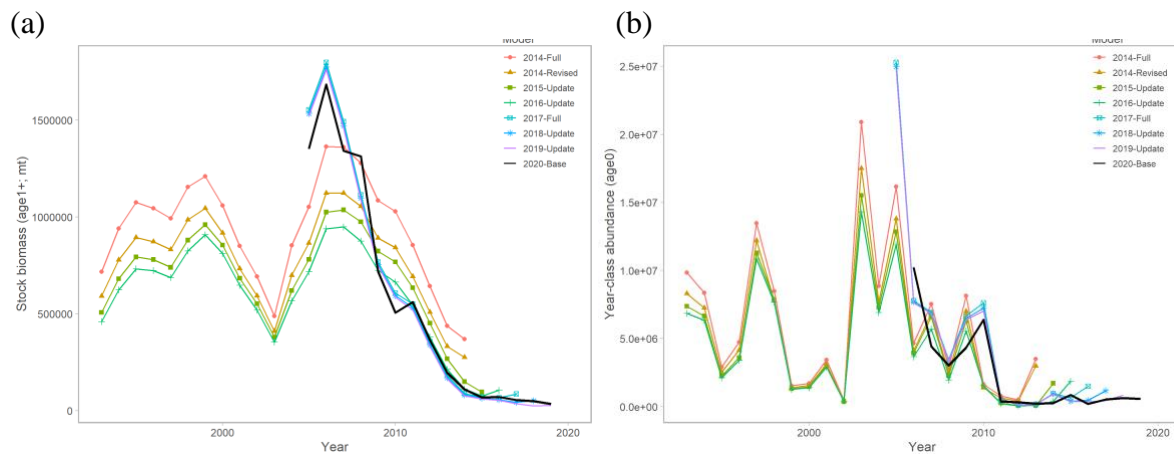


Figure 4. A comparison of time series for the 2020 final base model and past assessment models used for management for (a) estimated stock biomass (age 1+; mt), and (b) estimated recruits (age 0).

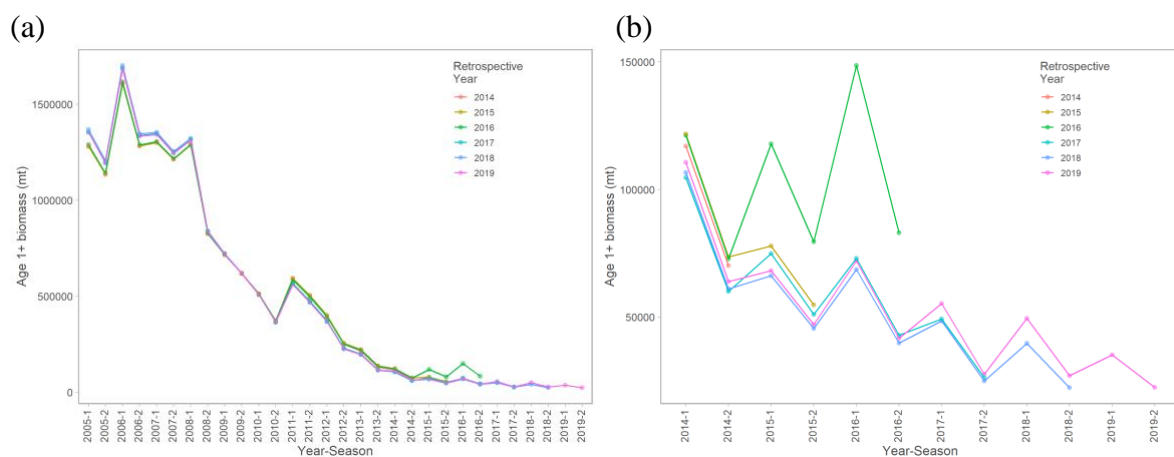


Figure 5. Retrospective analyses of stock biomass (age 1+) for 2020 final base model for (a) the whole time series, and (b) zooming in on recent years. [Note: the retrospective pattern for 2016 stands out from the other years due to higher recruitment deviations and a higher predicted index value.]

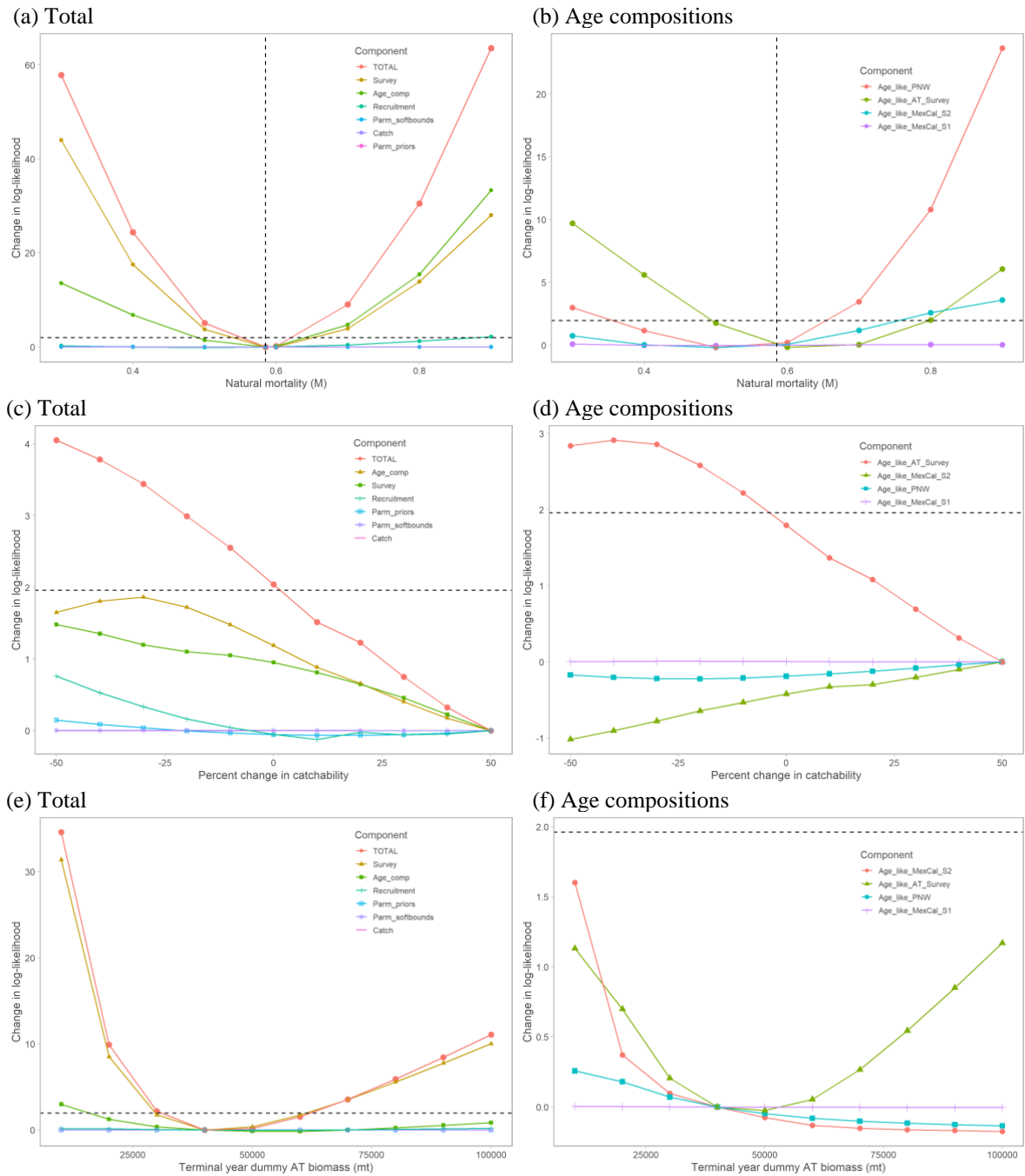


Figure 6. Likelihood profiles for the 2020 final base model across fixed values for (a) & (b) natural mortality, (c) & (d) percentage change in survey  $Q$  (for the two periods of  $Q$ ), and (e) & (f) terminal year dummy ATM biomass.

## Conclusions and recommendations

The Panel had several concerns about the proposed base model (model A in Annex 4): it ignored the substantial inshore biomass estimated by the CCPSS, a position that could not be sustained in the face of mounting evidence, both anecdotal and scientific; it estimated an unrealistically high fishing mortality for the years without observed catch data that required assumptions about the catch (model years 2019-2 onwards); the R1 offset parameter was not behaving as it should and had undue influence on the total likelihood; it was fitting (poorly) to

the spring ATM age composition data, for which the ALK was pooled over years, thus smearing any potential cohort signals in the data. These concerns were rectified by the STAT by: removing the prior on  $Q$  and, instead, setting  $Q$  equal to 1 for the years prior to 2015, and to the ratio of the ATM survey biomass for 2019 relative to the combined 2019 ATM survey and CCPSS biomass estimates from 2015 onward (0.733), which coincided with the first reports of substantial inshore biomass of sardine; assuming fishing effort has been constant since 2019, and therefore setting fishing mortality for model years 2019-2 onwards equal to the corresponding seasonal fishing mortality for the years 2018-2 and 2019-1; setting  $\lambda=0$  in the likelihood for the R1 offset parameter so that it was no longer contributing directly to the likelihood; removing the spring ATM age composition data from the model.

Further adjustments to the proposed base model also included fixing steepness at 0.3, because having fixed the R1 offset parameter (with  $\lambda=0$  in the likelihood), the model was no longer able to estimate steepness. I have concerns about this approach, and in particular that the reasons for this change in the model (not being able to estimate  $h$ ) needs to be better understood, and alternatives considered to fixing this parameter at what seems like an arbitrary value. Perhaps a prior could be developed for this parameter based on existing meta-analyses (e.g., Myers et al. 1999 or any more recent work), or consideration given to extending the model back in time.

It is also clear that the sardine assessment cannot estimate scale, because the proposed base model needs a highly informative prior on  $Q$  to prevent unrealistically high estimates of  $Q$ . The decision to remove the prior and set  $Q$  to fixed values is therefore a sensible one. Assuming  $Q$  to be 1 prior to 2015 appears to be reasonable given that the ATM surveys are believed to have covered most of the biomass in those years, while setting it to 0.733 from 2015 onwards reflects the increased proportion of the biomass believed to be inshore of the ATM survey coverage (coinciding with when reports from the industry started to emerge, and acknowledging the CCPSS estimates). Much work is still needed on getting the CCPSS integrated into the assessment, and this is reflected in the STAR Panel Report.

A number of recommendations arose from the review, and these were classified as high (H), medium (M) or low (L) priority. Most of them were “rolled over” from previous STAR Panel reviews and related to: the benefits of greater international cooperation (H); needed changes to the Stock Synthesis package (H); MSE examination of the current approach of basing the OFLs, ABCs and HGs for the current year on the previous year’s biomass estimate, but also including further development of the 2017 proposal for a survey projection method (H); alternative approaches for dealing with highly uncertain estimates of recruitment and their impact on 1+ biomass, important for management (H); reducing ageing error bias by coordinating and standardising age-reading techniques, improving methods of validation, and reporting comparative studies (H); exploring alternative fishery independent data sources (such as the SWFSC juvenile rockfish survey) (M); considering spatial models in order to better capture regional variations in population dynamics (M); modelling fleets separately (Mexico, California, Oregon-Washington, Canada) (M); comparing length compositions between Oregon-Washington and British Columbia to evaluate assumptions about age-structure between these regions (M); explicitly modelling sex structure (L); and developing a relationship between egg production and fish age that accounts for the duration of spawning, batch fecundity, etc. (L).

Recommendations that specifically arose from this review were the following (from the STAR Panel report):

- The final base model relies on the 2019 CCPSS estimate of biomass as the basis for recent Q. However, the ideal is to integrate these data into the assessment. Increased collaboration between SWFSC and CDFW scientists (and, ideally, inclusion of a CDFW scientist on the next STAT) is needed to achieve this goal. [H]
- Purse seine nets used in nearshore areas should utilize a mesh size that can catch anchovy effectively without leading to biased estimates of species composition. [H]
- The approach to estimating the variance of the CCPSS based on between-band variance will be flawed if the steep gradient in biomass from band 1 and 2 is confirmed by future surveys. Consideration should be given to estimating variance by temporal replication. [H]
- More biological samples should be collected during the CCPSS to allow length and age compositions to be estimated and these data included in a future assessment. It is more desirable that the CCPSS and AT results be combined to provide a more spatially complete index of total stock abundance at length and/or age. [H]
- Examine information on the attribution of catch and biomass between the northern and southern subpopulations. If the methodology used to conduct this split is substantially different from the current approach, it will be necessary to conduct a Methodology Review. [H]
- Add a bycatch fleet for MexCal S2 that has zero catch for all but the last two years, where catch is a function of the fishing mortality rate in the last year with data so that the 2019 fishing mortality rate is a function of the data. [H]
- Evaluate the model sensitivity to the input weight-at-age, and/or to have a deeper think on how uncertainty in the input weight-at-age could/should be characterized because these data are from the AT trawl samples. [H]
- Further investigate the catch data from Ensenada to (a) quantify uncertainty in the estimates of northern subpopulation catches, (b) examine how sensitive the estimates of northern subpopulation catch are to how the habitat model is applied. [M]
- Obtain ageing data for northern subpopulation fish from the Ensenada fishery to allow testing of the hypothesis that the age-structure of the Ensenada catch matches that of the catches off California. Care should be taken to ensure that a common ageing protocol is followed for ageing of fish off Ensenada and California. [M]
- A single length-weight relationship is used for all years and seasons. The data on length and weight should be analysed to assess whether this relationship varies between seasons and over time. [L]

## Comments on Terms of Reference

The terms of reference are given in “Background” above and in Appendix 2 of Annex 2. As a CIE reviewer, I participated fully in the activities of the STAR Panel, and provide full support to, and endorse the Panel’s findings and recommendations, as reflected in their report. Comments on the individual terms of reference are already provided in italics in the “Background” section.

## Comments on NMFS review process

The review process was thorough, but also fast-moving. Although understanding of the difficulty of doing it (lack of time and personnel, and volume of material), the one thing I did find frustrating was that none of the model results produced during the meeting were automatically made available on the FTP site, either during the meeting or afterwards. This may be related to a new person taking over the assessment (he did a very good job), and not being fully aware of this need for the purposes of review. I found that this did hamper slightly the review process for me, particularly when compiling this report (as I wanted to give careful consideration to all the model results covered during the meeting). This meant that I could not check the accuracy of Annex 4 for model details and their links to requests. If the volume of material was a concern, then even just making available the report.sso files for all model runs would have been helpful. As a caveat to this, I must add that when I did ask for information, it was always provided. However, the meeting did sometimes feel like it was focussed on those well-versed in the details of the northern subpopulation of sardine, and this did not help the review process for outside reviewers (lack of more detail on underlying data, and on model results). Apart from this, I found the review to be well-run, professionally handled and very informative, and I was appreciative of the efforts of the STAT to provide everything needed for the review, and of the organisers for their background work to ensure a smoothly run meeting.

## References

Myers, R. A., Bowen, K. G., and Barrowman, N. J. 1999. Maximum reproductive rate of fish at low population sizes. *Canadian Journal of Fisheries and Aquatic Sciences*, 56: 2404–2419.



## Annex 1: Bibliography of materials provided for review

[ftp site: [ftp://ftp.pcouncil.org/pub/2020\\_Sardine\\_STAR\\_panel/](ftp://ftp.pcouncil.org/pub/2020_Sardine_STAR_panel/)]

### **Materials provided prior to the start of the STAR Panel Review meeting**

#### **ATM and aerial surveys**

Lynn, Kirk, Porzio, Dianna and Trung Nguyen. 2020. California Coastal Pelagic Species Survey Results from Summer 2017 and 2019 for Pacific Sardine (*Sardinops sagax*): 15pp. [CCPSS\_Report\_SardineSTAR\_Feb2020.pdf]

Stierhoff, Kevin L., Juan P. Zwolinski, and David A. Demer. 2019. Distribution, biomass, and demography of coastal pelagic fishes in the California Current Ecosystem during summer 2018 based on acoustic-trawl sampling. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-613: 83pp. [NOAA-TM-NMFS-SWFSC-613.pdf]

Stierhoff, Kevin L., Juan P. Zwolinski, and David A. Demer. 2020. Distribution, biomass, and demography of coastal pelagic fishes in the California Current Ecosystem during summer 2019 based on acoustic-trawl sampling. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-626: 87pp. <https://doi.org/10.25923/nghv-7c40>. [2019 ATM biomass report - Stierhoff et al.pdf]

Stierhoff, Kevin L., Juan P. Zwolinski, Josiah S. Renfree, and David A. Demer. 2017. Report on the collection of data during the acoustic-trawl and daily egg production methods survey of coastal pelagic fish species and krill (1504sh) within the California current ecosystem, 28 March to 1 May 2015, conducted aboard fisheries survey vessel. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-580: 25pp. [NOAA-TM-NMFS-SWFSC-580.pdf]

Stierhoff, Kevin L., Juan P. Zwolinski, Josiah S. Renfree, Gabriel E. Johnson, Scott A. Mau, David W. Murfin, Thomas S. Sessions, and David A. Demer. 2020. Report on the Summer 2019 California Current Ecosystem Survey (1907RL), 13 June to 9 September 2019, conducted aboard NOAA Ship Reuben Lasker, fishing vessels Lisa Marie and Long Beach Carnage, and three unmanned sailboats. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-625: 49pp. [2019 ATM survey report - Stierhoff et al.pdf]

Zwolinski, Juan P., Kevin L. Stierhoff, and David A. Demer. 2019. Distribution, biomass, and demography of coastal pelagic fishes in the California Current Ecosystem during summer 2017 based on acoustic-trawl sampling. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-610:76pp. [NOAA-TM-NMFS-SWFSC-610.pdf]

#### **Methodology reviews**

SSC. 2017. Southern California Coastal Pelagic Species Aerial Survey Methodology Review. NOAA / Southwest Fisheries Science Center, La Jolla, California, April 17-18, 2017. Agenda Item D.2, Attachment 1, June 2017: 22pp [Aerial survey methodology review report 2017.pdf]

SSC. 2018. Methodology Review Panel report: acoustic trawl methodology review for use in coastal pelagic species stock assessments. National Marine Fisheries Service (NMFS),

Southwest Fisheries Science Center (SWFSC), La Jolla, California, 29 January - 2 February 2018. Agenda Item C.3, Attachment 2, April 2018: 75pp. [ATM review report 2018.pdf]

### **Previous assessment reports and reviews**

Hill, K.T., P.R. Crone, and J.P. Zwolinski. 2017. Assessment of the Pacific sardine resource in 2017 for U.S. management in 2017-18. Pacific Fishery Management Council, April 2017. Briefing Book, Agenda Item G.5.a, Portland, Oregon. 146 p. [2017 stock assessment.pdf] [Duplicate copy provided during meeting: 2017 stock assessment\_G5a\_Stock\_Assessment\_Rpt\_Full\_ElectricOnly\_Apr2017BB.pdf]

Hill, K.T., P.R. Crone, and J.P. Zwolinski. 2019. Assessment of the Pacific sardine resource in 2019 for U.S. management in 2019-20. Agenda Item E.3, Supplemental REVISED Attachment 1 (Full version electronic only), April 2019: 116pp. [2019 Update assessment.pdf]

SSC. 2017. Scientific and Statistical Committee report on final action on sardine assessment, specifications, and management measures. Agenda Item G.5.b, Supplemental SSC Report, April, 2017:1pp. [2017 SSC report on sardine assessment.pdf] [Duplicate copy: 2017 SSC report.pdf] [Duplicate copy provided during meeting: 2017 SSC report\_G5b\_Sup\_SSC\_Rpt\_SardineAssessment\_Apr2017BB.pdf]

SSC. 2019. Scientific and Statistical Committee report on Pacific sardine assessment, harvest specifications, and management measures – final action. Agenda Item E.3.a, Supplemental SSC Report 1, April 2019: 4pp. [2019 SSC report.pdf]

SSC. 2019. Draft Summary Minutes: 26pp. [2019 SSC\_Minutes\_including sardine subcommittee report.docx] [Duplicate copy provided during meeting: 2019\_SSC\_Minutes\_April2019\_DRAFT\_JUNE2019BB.docx]

STAR Panel. 2017. Pacific Sardine STAR Panel Meeting Report. Agenda item G.5.a, STAR Panel Report, April 2017: 24pp. [2017 STAR panel report.pdf] [Duplicate copy provided during meeting: 2017 STAR panel rpt\_G5a\_STAR\_Panel\_Rpt\_Apr2017BB.pdf]

### **Stock assessment report, 2020**

Kuriyama, P.T., Zwolinski J.P., Hill, K.T., and Crone, P.R. 2020. Assessment of the Pacific sardine resource in 2020 for U.S. management in 2020-2021. Pacific Fishery Management Council, Portland, OR: 119pp. Available from <https://www.pcouncil.org/coastal-pelagic-species/stock-assessment-and-fishery-evaluation-safe-documents/> [DRAFT sardine assessment Feb 10.pdf]

### **Other documents**

Privitera-Johnson, K. M. and A. E. Punt. 2019. Estimating among-assessment variation in overfishing limits. Agenda Item G.3, Attachment 1, March 2019: 66pp [G3\_Att1\_PriviteraJohnson\_Estimating\_sigma\_SSC\_MAR2019BB.pdf]

Privitera-Johnson, K. M. and A. E. Punt. 2019. Addendum – Estimating among-assessment variation in overfishing limits Agenda Item G.3, Attachment 2, March 2019: 11pp. [G3\_Att2\_AddendumPriviteraJohnson\_Estimatingsigma\_Feb7.pdf]

SSC and CPC Subcommittees. 2019. SSC Groundfish and Coastal Pelagic Species Subcommittees' Report on the Steepness Prior and Sigma Review Meeting Held on 01 November 2018. Agenda Item G.3.a, SSC Groundfish and CPS Subcommittees Report 1, March 2019: 10pp. [G3a\_SSC\_GF&CPS\_Subcms\_Report1-Steepness\_Prior\_&\_Sigma\_Review\_MAR2019BB.docx]

Wetzel, C. R. and O. Hamel. Accounting for increased uncertainty in setting precautionary harvest limits from past assessments. Agenda Item G.3, Supplemental REVISED Attachment 3, March 2019: 21pp. [G3\_Supp\_REVISED\_Att3\_Wetzel\_Sigma\_Evaluation\_MAR2019BB.pdf]

### **Materials provided during the STAR Panel Review meeting**

#### **Presentations**

##### *Assessment of the Pacific Sardine Resource in 2020*

Peter Kuriyama presented (authors were the STAT team: Peter T. Kuriyama, Juan P. Zwolinski, Kevin T. Hill, Paul R. Crone) [sardine2020 Kuriyama.pptx]

##### *Distribution, biomass, and demography of coastal pelagic fishes in the California Current Ecosystem during summer 2019 based on acoustic-trawl sampling*

Juan Zwolinski presented (authors: Juan P. Zwolinski, Kevin L. Stierhoff, David A. Demer, and many others) [Zwolinski\_STAR\_2020 ATM presentation.pdf]

##### *California Coastal Pelagic Species Survey: Results from summer 2017 and 2019 for Pacific sardine (*Sardinops sagax*)*

Kirk Lynn presented (authors: Kirk Lynn, Dianna Porzio, Trung Nguyen) [CCPSS\_2020\_Sardine\_STAR Lynn.pdf]

#### **Further documents**

Hill, Kevin T., Paul R. Crone, Nancy C. H. Lo, Beverly J. Macewicz, Emmanis Dorval, Jennifer D. McDaniel, and Yuhong Gu. 2011. Assessment of the Pacific sardine resource in 2011 for U.S. management in 2012. Agenda Item F.2.b, Supplemental (Full Document; Electronic Only) Attachment 8, Pacific Sardine Assessment Report, November 2011: 6pp [2011\_Juv rockfish survey appendix in 2011 sardine assessment.pdf]

Dorval, E., D. Porzio, and J. Walker. 2019. Ageing precision of Pacific sardine (*Sardinops Sagax*) collected during the California Current Ecosystem Survey in summer 2017-2018. Working Paper, December 2019: 15pp [Psard\_Ageing Error Working Paper-123019 Dorval.pdf]

## **Requests**

*The following files, in response to several requests, were uploaded:*

CCPSS\_Sardine STAR\_200226\_rev.pdf  
day4\_longts Kuriyama.png  
day4\_shortts Kuriyama.png  
Distance to shore\_2020-02-25 Juan.png  
ENS Catch New-Old Hill.xlsx  
ENS-SCA-CCA Lengths Hill.xlsx  
Kuriyama\_starday1.pdf  
peter\_day2\_am.docx  
reareyousendingthoserevisedplots.zip  
Request 7\_NCS point set Lynn.xlsx  
Requests\_24\_Feb\_2020 REV.docx  
Requests\_24\_Feb\_2020 REV\_with\_responses.docx  
Requests\_24\_Feb\_2020.docx  
Requests\_25\_Feb\_am\_with\_responses.docx  
Requests\_25\_Feb\_pm.docx  
Requests\_25\_Feb\_pm\_peter.docx  
Requests\_25\_Feb\_pm\_with\_responses.docx  
Requests\_26\_Feb\_pm.docx  
Response 12-Updated Equation & Computation of Variance Dorval.docx  
Response 12-Updated Equation & Computation of Variance-updated.docx  
Response to Request 6-Summary Tables Dorval.docx  
Response to Request 6-Summary Tables\_updated.docx  
Response to Request 8-Updated Dorval.docx

## **Public comment**

*The following files were uploaded:*

CA Fishermen's Questions notes and observations.pdf  
Richard Parrish Comment 1-2020 Assessment.pdf  
Richard Parrish Comment 2 for Sardine STAR Panel Meeting.pdf

## **Materials provided after the STAR Panel Review meeting**

On request, Peter Kuriyama provided model outputs and plots for the final base run.

## Annex 2: Copy of CIE Statement of Work

**Performance Work Statement**  
**National Oceanic and Atmospheric Administration (NOAA)**  
**National Marine Fisheries Service (NMFS)**  
**Center for Independent Experts (CIE) Program**  
**External Independent Peer Review**

***STAR Panel Review of the 2020-2021 Pacific Sardine Stock Assessment***

***February 24-27, 2020***

### **Background**

The National Marine Fisheries Service (NMFS) is mandated by the Magnuson-Stevens Fishery Conservation and Management Act, Endangered Species Act, and Marine Mammal Protection Act to conserve, protect, and manage our nation's marine living resources based upon the best scientific information available (BSIA). NMFS science products, including scientific advice, are often controversial and may require timely scientific peer reviews that are strictly independent of all outside influences. A formal external process for independent expert reviews of the agency's scientific products and programs ensures their credibility. Therefore, external scientific peer reviews have been and continue to be essential to strengthening scientific quality assurance for fishery conservation and management actions.

Scientific peer review is defined as the organized review process where one or more qualified experts review scientific information to ensure quality and credibility. These expert(s) must conduct their peer review impartially, objectively, and without conflicts of interest. Each reviewer must also be independent from the development of the science, without influence from any position that the agency or constituent groups may have. Furthermore, the Office of Management and Budget (OMB), authorized by the Information Quality Act, requires all federal agencies to conduct peer reviews of highly influential and controversial science before dissemination, and that peer reviewers must be deemed qualified based on the OMB Peer Review Bulletin standards. ([http://www.cio.noaa.gov/services\\_programs/pdfs/OMB Peer Review Bulletin m05-03.pdf](http://www.cio.noaa.gov/services_programs/pdfs/OMB_Peer_Review_Bulletin_m05-03.pdf)).

Further information on the CIE program may be obtained from [www.ciereviews.org](http://www.ciereviews.org).

### **Scope**

The CIE reviewers will serve on a Stock Assessment Review (STAR) Panel and will be expected to participate in the review of Pacific sardine stock assessment. The Pacific sardine stock is assessed regularly (currently, every year) by SWFSC scientists, and the Pacific Fishery Management Council (PFMC) uses the resulting biomass estimate to establish an annual harvest guideline (quota). The stock assessment data and model are formally reviewed by a Stock Assessment Review (STAR) Panel once every three years, with a coastal pelagic species subcommittee of the Scientific and Statistical Committee (SSC) reviewing updates in interim years. Independent peer review is required by the PFMC review process. The STAR Panel will review draft stock assessment documents and any other pertinent information for Pacific sardine, work with the stock assessment teams to make necessary revisions, and produce a

STAR Panel report for use by the PFMC and other interested persons for developing management recommendations for the fishery. The PFMC's Terms of Reference (ToRs) for the STAR Panel review are attached in Appendix 1. The tentative agenda of the Panel review meeting is attached in Appendix 2. Finally, a Panel summary report template is attached as Appendix 3.

### **Requirements**

Two CIE reviewers shall participate during a panel review meeting in La Jolla, California during 24-27 February, and shall conduct an impartial and independent peer review accordance with this Performance Work Statement (PWS) and ToRs herein. The CIE reviewers shall have the expertise as listed in the following descending order of importance:

- The CIE reviewer shall have expertise in the design and execution of fishery-independent surveys for use in stock assessments, preferably with coastal pelagic fishes.
- The CIE reviewer shall have expertise in the application of fish stock assessment methods, particularly, length/age-structured modeling approaches, e.g., 'forward-simulation' models (such as Stock Synthesis, SS) and it is desirable to have familiarity in 'backward-simulation' models (such as Virtual Population Analysis, VPA).
- The CIE reviewer shall have expertise in the life history strategies and population dynamics of coastal pelagic fishes.
- It is desirable for the CIE reviewer to be familiar with the design and application of fisheries underwater acoustic technology to estimate fish abundance for stock assessment.
- It is desirable for the CIE reviewer to be familiar with the design and application of aerial surveys to estimate fish abundance for stock assessment.

The CIE reviewer's duties shall not exceed a maximum of 14 days to complete all work tasks of the peer review process.

### **Tasks for reviewers**

- Review the following background materials and reports prior to the review meeting:  
*Two weeks before the peer review, the NMFS Project Contact will send by electronic mail or make available at an FTP site to the CIE reviewers all necessary background information and reports for the peer review. In the case where the documents need to be mailed, the NMFS Project Contact will consult with the CIE on where to send documents. The CIE reviewers shall read all documents in preparation for the peer review, for example:*
  - *Recent stock assessment documents since 2013;*
  - *STAR Panel- and SSC-related documents pertaining to reviews of past assessments;*
  - *CIE-related summary reports pertaining to past assessments; and*
  - *Miscellaneous documents, such as the PWS, logistical considerations.*

*Pre-review documents will be provided up to two weeks before the peer review. Any delays in submission of pre-review documents for the CIE peer review will result in delays with the CIE peer review process, including a PWS modification to the schedule of milestones and deliverables. Furthermore, the CIE reviewers are responsible only for the pre-review documents that are delivered to the reviewer in accordance to the PWS scheduled deadlines specified herein.*

- Attend and participate in the panel review meeting
  - The meeting will consist of presentations by NOAA and other scientists, stock assessment authors and others to facilitate the review, to provide any additional information required by the reviewers, and to answer any questions from reviewers
- After the review meeting, reviewers shall conduct an independent peer review in accordance with the requirements specified in this PWS, OMB guidelines, and TORs, in adherence with the required formatting and content guidelines; reviewers are not required to reach a consensus
- Each reviewer may assist the Chair of the meeting with contributions to the summary report, if required by the TORs
- Deliver their reports to the Government according to the specified milestone dates

#### **Foreign National Security Clearance**

When reviewers participate during a panel review meeting at a government facility, the NMFS Project Contact is responsible for obtaining the Foreign National Security Clearance approval for reviewers who are non-US citizens. For this reason, the reviewers shall provide requested information (e.g., first and last name, contact information, gender, birth date, passport number, country of passport, travel dates, country of citizenship, country of current residence, and home country) to the NMFS Project Contact for the purpose of their security clearance, and this information shall be submitted at least 30 days before the peer review in accordance with the NOAA Deemed Export Technology Control Program NAO 207-12 regulations available at the Deemed Exports NAO website: <http://deemedexports.noaa.gov/> and [http://deemedexports.noaa.gov/compliance\\_access\\_control\\_procedures/noaa-foreign-national-registration-system.html](http://deemedexports.noaa.gov/compliance_access_control_procedures/noaa-foreign-national-registration-system.html). The contractor is required to use all appropriate methods to safeguard Personally Identifiable Information (PII).

#### **Place of Performance**

The place of performance shall be at the contractor's facilities, and at the NMFS Southwest Fisheries Science Center in La Jolla, California.

#### **Period of Performance**

The period of performance shall be from the time of award through April 30, 2020. Each reviewer's duties shall not exceed 14 days to complete all required tasks.



**Schedule of Milestones and Deliverables:** The contractor shall complete the tasks and deliverables in accordance with the following schedule.

<b>Schedule</b>	<b>Milestones and Deliverables</b>
<i>January 27, 2020</i>	CIE sends reviewers contact information to the COTR, who then sends this to the NMFS Project Contact
<i>No later than February 10, 2020</i>	NMFS Project Contact sends the CIE Reviewers the pre-review documents
<b>February 24-27, 2020</b>	The reviewers participate and conduct an independent peer review during the panel review meeting
<i>Within two weeks after review</i>	Contractor receives draft reports and summary report
<i>Within two weeks of receiving draft reports</i>	Contractor submits final reports to the Government

#### **Applicable Performance Standards**

The acceptance of the contract deliverables shall be based on three performance standards:  
(1) The reports shall be completed in accordance with the required formatting and content  
(2) The reports shall address each TOR as specified  
(3) The reports shall be delivered as specified in the schedule of milestones and deliverables.

#### **Travel**

All travel expenses shall be reimbursable in accordance with Federal Travel Regulations (<http://www.gsa.gov/portal/content/104790>). International travel is authorized for this contract.

#### **Restricted or Limited Use of Data**

The contractors may be required to sign and adhere to a non-disclosure agreement.

## **Peer Review Report Requirements**

1. The report must be prefaced with an Executive Summary providing a concise summary of the findings and recommendations, and specify whether or not the science reviewed is the best scientific information available.
2. The report must contain a background section, description of the individual reviewers' roles in the review activities, summary of findings for each TOR in which the weaknesses and strengths are described, and conclusions and recommendations in accordance with the TORs.
  - a. Reviewers must describe in their own words the review activities completed during the panel review meeting, including a brief summary of findings, of the science, conclusions, and recommendations.
  - b. Reviewers should discuss their independent views on each TOR even if these were consistent with those of other panellists, but especially where there were divergent views.
  - c. Reviewers should elaborate on any points raised in the summary report that they believe might require further clarification.
  - d. Reviewers shall provide a critique of the NMFS review process, including suggestions for improvements of both process and products.
  - e. The report shall be a stand-alone document for others to understand the weaknesses and strengths of the science reviewed, regardless of whether or not they read the summary report. The report shall represent the peer review of each TOR, and shall not simply repeat the contents of the summary report.
3. The report shall include the following appendices:
  - Appendix 1: Bibliography of materials provided for review
  - Appendix 2: A copy of this Statement of Work
  - Appendix 3: Panel membership or other pertinent information from the panel review meeting.

## Appendix 1: Terms of Reference for the Peer Review of the Pacific sardine stock assessment

The CIE reviewers are one of the four equal members of the STAR panel. The principal responsibilities of the STAR Panel are to review stock assessment data inputs, analytical models, and to provide complete STAR Panel reports.

Along with the entire STAR Panel, the CIE Reviewer's duties include:

1. Reviewing draft stock assessment and other pertinent information (e.g.; previous assessments and STAR Panel reports);
2. Working with Stock Assessment Team (STAT) Teams to ensure assessments are reviewed as needed;
3. Documenting meeting discussions;
4. Reviewing summaries of stock status (prepared by STAT Teams) for inclusion in the Stock Assessment and Fishery Evaluation (SAFE) document;
5. Recommending alternative methods and/or modifications of proposed methods, as appropriate during the STAR Panel meeting, and;
6. The STAR Panel's terms of reference concern technical aspects of stock assessment work. The STAR Panel should strive for a risk neutral approach in its reports and deliberations.

The STAR Panel, including the CIE Reviewers, are responsible for determining if a stock assessment or technical analysis is sufficiently complete. It is their responsibility to identify assessments that cannot be reviewed or completed for any reason. The decision that an assessment is complete should be made by Panel consensus. If agreement cannot be reached, then the nature of the disagreement must be described in the Panels' and CIE Reviewer's reports.

The review solely concerns technical aspects of stock assessment. It is therefore important that the Panel strive for a risk neutral perspective in its reports and deliberations. Assessment results based on model scenarios that have a flawed technical basis, or are questionable on other grounds, should be identified by the Panel and excluded from the set upon which management advice is to be developed. The STAR Panel should comment on the degree to which the accepted model scenarios describe and quantify the major sources of uncertainty. Confidence intervals of indices and model outputs, as well as other measures of uncertainty that could affect management decisions, should be provided in completed stock assessments and the reports prepared by STAR Panels.

Recommendations and requests to the STAT Team for additional or revised analyses must be clear, explicit, and in writing. A written summary of discussion on significant technical points and lists of all STAR Panel recommendations and requests to the STAT Team are required in the STAR Panel's report. This should be completed (at least in draft form) prior to the end of the meeting. It is the chair and Panel's responsibility to carry out any follow-up review of work that is required.

## Appendix 2: DRAFT AGENDA: 2020 PACIFIC SARDINE STAR PANEL

### Monday, 24 February

08h30	Call to Order and Administrative Matters	
	Introductions	Punt
	Facilities, e-mail, network, etc.	Sweetnam
	Work plan and Terms of Reference	Griffin
	Report Outline and Appointment of Rapporteurs	Punt
09h00	Pacific Sardine survey-based assessment presentation	Kuriyama/Hill/Crone
10h00	Break	
10h30	Pacific Sardine model-based assessment presentation	Kuriyama/Hill/Crone
11h30	Acoustic and trawl survey	Zwolinski, ATM group
12h00	Lunch	
13h30	Pacific Sardine assessment presentation (continue)	Kuriyama/Hill/Crone
14h30	Panel discussion and analysis requests	Panel
15h00	Break	
15h30	Public comments and general issues	
17h00	Adjourn	

### Tuesday, 25 February

08h00.	Assessment Team Responses	Kuriyama/Hill/Crone
10h30	Break	
11h00.	Discussion and STAR Panel requests	Panel
12h30	Lunch	
13h30	Report drafting	Panel
15h00	Break	
15h30	Assessment Team Responses	Kuriyama/Hill/Crone
16h30	Discussion and STAR Panel requests	
17h00	Adjourn	

### Wednesday, 26 February

08h00.	Assessment Team Responses	Kuriyama/Hill/Crone
10h30	Break	
11h00.	Discussion and STAR Panel requests	Panel
12h30	Lunch	
13h30	Report drafting	Panel
15h00	Break	
15h30	Assessment Team Responses	Kuriyama/Hill/Crone
16h30	Discussion and STAR Panel requests	
17h00	Adjourn	

### Thursday, 27 February

08h00.	Assessment Team Responses	Kuriyama/Hill/Crone
10h30	Break	
11h00.	Discussion and STAR Panel requests	Panel
12h30	Lunch	
13h30	Finalize STAR Panel Report	Panel
15h00	Break	
15h30	Finalize STAR Panel Report	Panel
17h00	Adjourn	

### Appendix 3: STAR Panel Summary Report (Template)

- Names and affiliations of STAR Panel members
- List of analyses requested by the STAR Panel, the rationale for each request, and a brief summary the STAT responses to each request
- Comments on the technical merits and/or deficiencies in the assessment and recommendations for remedies
- Explanation of areas of disagreement regarding STAR Panel recommendations
  - Among STAR Panel members (including concerns raised by the CPSMT and CPSAS representatives)
  - Between the STAR Panel and STAT Team
- Unresolved problems and major uncertainties, e.g., any special issues that complicate scientific assessment, questions about the best model scenario, etc.
- Management, data or fishery issues raised by the public and CPSMT and CPSAS representatives during the STAR Panel
- Prioritized recommendations for future research and data collection

## Annex 3: STAR Panel membership and other pertinent information

### Attendance List – Pacific Sardine STAR Panel February 2020

<b>Name</b>	<b>Affiliation</b>
<i>Stock Assessment Review Panel</i>	
André Punt	SSC/University of Washington, Chair
Noel Cadigan	CIE
Melissa Haltuch	SSC/NWFSC
José De Oliveira	CIE
Marisol García-Reyes	SSC/Farallon Institute
<i>Advisers</i>	
Diane Pleschner-Steele	CPSAS
Alan Sarich	CPSMT
<i>Stock Assessment Team</i>	
Peter Kuriyama	SWFSC
Juan Zwolinski	SWFSC
Kevin Hill	SWFSC
Paul Crone	SWFSC
<i>Other attendees</i>	
Dale Sweetnam	SWFSC
Kirk Lynn	CPSMT/CDFW
Kerry Griffin	PFMC
Lynn Massey	NMFS WCR
Josh Lindsay	NMFS WCR
Kelsey James	SWFSC
Brittany Schwartzkopf	SWFSC
John Budrick	CDFW
Trung Nguyen	CDFW
Briana Brady	CDFW
James Gardner	Oceanside Bait Company
Vince Torre	Trimarine
Corbin Hansen	F/V Cape Blanco
Nick Jurlin	
Steve Crooke	CPSAS
Kristen Koch	SWFSC
James Hilger	SWFSC
Kristin Roll	SWFSC
Diana Porzio	CDFW
Bev Macewicz	SWFSC
Emmanis Dorval	SWFSC
Anthony Russo	F/V King Philip
Tom Brinton	F/V Long Beach Carnage
Jamie Ashley	Long Beach Bait Company

Mike Conroy	West Coast Fisheries Consultants
Peter Ciaranitaro	Triton Fishing
Jason Dunn	Everingham Bait Company
Chilli Pepperdnoth	
Alayna Siddall	Sportfishing Association of California
Don Hansen	PFMC
David Haworth	
Gwendal Le Fol	
Huihua Lee	SWFSC
Annie Yao	SWFSC

CDFW = California Department of Fish and Wildlife

CIE = Center of Independent Experts

CPSAS = Coastal Pelagic Species Advisory Subpanel

CPSMT = Coastal Pelagic Species Management Team

NMFS WCR = National Marine Fisheries Service West Coast Region

NWFSC = Northwest Fisheries Science Center

PFMC = Pacific Fishery Management Council

SSC = Scientific and Statistical Committee

SWFSC = Southwest Fisheries Science Center



## Annex 4: Relevant information from STAR Panel Report

Table A4.1. Requests, Rationale and Responses from STAR Panel Report (with minor edits). Models are referenced in Annex 5. [Note: where applicable, all Figures and Tables referred to in the following table refer back to the STAR Panel Report, unless otherwise indicated. Note also that the Model names are my own to help keep track of all the models run.]

Nr	Request	Rationale	Response	Model(s)
1	Provide a plot of the catches and age- and length-compositions for the non-directed fishery.	These data are included in a model sensitivity run but are not shown in the document.	The STAT provided the requested figures for the 2005 to 2019 catches. The incidental catches (INC) largely come from the MexCal region. Although INC length comps are not included in the model, a comparison was made with the implied model length comps.	
2	Add sample sizes to the weight-at-age plots for all fleets and surveys (or create a table).	The weight-at-age by cohort has odd behaviour at older ages in some years; this may be due to small sample sizes.	There are very few samples for ages beyond 4-5 because fish of these ages are not frequently observed (MexCal S1 and S2). The PNW sample sizes are larger at older ages in some, but not all, years. The AT samples have larger sample sizes for older ages (up to about age 7) in some, but not all, years.	
3	Summarize how acoustic backscatter is converted to biomass estimates and how the variance for the estimates of biomass are calculated.	The Panel wished to fully understand the current methods, which were previously reviewed by the SSC.	The document titled 'Distribution, biomass, and demography of coastal pelagic fishes in CCE during summer 2019 based on acoustic trawl sampling', page 25 was provided. The discussion noted that the greatest driver of variability is spatial variation in the acoustic backscatter by transect, and that variance may still be an underestimate owing to not accounting for uncertainty due to the locations of the trawls, but likely not by much.	
4	Provide a table that shows the nearshore extent of each survey method (acoustic trawl, sail drone, commercial vessel, and aerial survey).	The Panel wished to better understand each survey region and the extent to which the area covered by each survey type overlaps.	A figure of the count of point set distances from the coast was provided (LBC=Long Beach Carnage, LM=Lisa Marie, RL=Reuben Lasker, SD=sail drone) for 2019. It was noted that the LBC (nearshore acoustic survey using the fishing vessel Carnage) and the CCPSS could overlap in southern California. However, the CCPSS data in this assessment were collected from north of Point Conception. The question of whether the sail drone and CCPSS overlap spatially was raised, but it was concluded that any overlap was minimal because most sardine observations are in the most nearshore band of the CCPSS.	
5	Document the methods used to model the age-length keys. Show residual	Modelling methods have changed from using a multinomial to using a cumulative logistic. It is difficult to evaluate how well	The STAT provided residual plots. It was concluded that there are no obvious residual patterns. The STAT provided documentation	

Nr	Request	Rationale	Response	Model(s)
	plots from the model fits (observed – expected) or metric of goodness of fit.	the model fits the data given the plots included in the draft report.	of methods with equations, which were included in the STAR panel report as an Appendix.	
6	Provide a table that summarizes changes in ageing methods and staff (by fleet). Also, provide a summary of ageing protocols by lab, which labs provide ages for which fleet, and any analyses of between-lab age reading comparisons.	The history of changes in ageing methods (readers and techniques) and which lab provides ages for which fleet is not clear. Ages are important in the model because the assessment pre-specifies weight-at-age.	Summary tables were provided. It was noted that systematic sardine ageing started in 2005, and that double reads between CDFW and SWFSC are used to estimate ageing error between labs. Ageing error is computed by lab, as is commonly done, and not by age reader. It was also noted that reader 2 has the most experience in ageing sardine and that this reader has been involved in ageing sardine in most years. The method used to estimate age-reading error matrices assumes one reader is unbiased – this is taken to be reader 2 as this reader is the most experienced one. It is common to have ages show $\pm$ one year difference due to difficulties in determining the first marginal increment. The Panel noted that different labs are using different methods, Mexico in particular. The other labs use more similar methods. Data from Mexico are not used in the assessment, and the model makes the assumption that the age data from California are representative of the Mexican catch (see request 10).	
7	Plot the point set data for the aerial survey showing the observer estimates and landed catches.	The Panel wished to better understand how visual estimates from observers compare to captured biomass. What proportion of the visually estimated biomass is covered by the catch data?	A figure of adjusted landed catch and estimated school biomass was provided. The plot confirms good estimation of school size biomass up to about 100t. Additional information on the proportion of the visually estimated biomass that is covered by the catch data was provided for request 11.	
8	Provide the methods for estimating biomass and variance by stratum for the CCPSS survey. Provide the sum of the biomass estimated from each CCPSS survey stratum, along with the variance. Calculate the annual CV using the sum of variances rather than the sum of CVs.	The Panel wished to understand how the aerial survey estimates of inshore biomass were determined and to correct the CVs used in the draft document.	The Nearshore Cooperative Survey (NCS) was the experimental phase of what is now the CCPSS survey. This survey design had multiple flights in a day over the same transect and concluded that spatial variation can act as a proxy for temporal variation. It was noted that when the number of schools are high, the observer provides only a combined estimate of biomass because fish are moving. Two observers were used in the NCS. The implementation phase of the survey is the CCPSS, which has one observer. Methods for analyzing the data from this survey were provided in an Appendix.	
9	Provide a table on apportionment of southern and northern stock catches for the past few years.	The Panel wished to better understand the consequences of the change to the method	The STAT provided tables of catches comparing the catches by the MexCal fleet and off Ensenada. The Mexican catches are more uncertain than those in the US. The Panel discussed the	

Nr	Request	Rationale	Response	Model(s)
		used to assign catches to the two subpopulations.	uncertainty in the proportion of the stock caught in Ensenada and how to obtain an upper and lower bound on Mexican catches, particularly for the years that influence the forecast (2019 and 2020).	
10	This request follows from Request 5. Verify that ages are similar for Mexico and California by showing the length frequencies for each fleet.	This is important because there are no Mexican age data and this comparison serves as a test of the assumption that California ages are representative of Mexico.	Data show that Ensenada lengths are typically similar or larger than those from California. However, the data are variable, rather than being systematically different. It was noted that it would be beneficial to get age data from Mexico in the future, which would require coordination of methods between ageing labs.	
11	This request follows from request 8. Provide the sum of the biomasses for each CCPSS band. Compute the variance as documented in the Appendix.	Correct the data.	A table of corrected values was provided. The Panel discussed the need for multiple flights over the same band if this survey is to continue, as it is clear that there are differences in the distribution of fish between bands. CCPSS observed school sizes were also presented (following on request 7), as well as length compositions (NDF for 2017 and NCS for 2019) and point set distances from shore. The Panel noted that the school sizes for the 2019 CCPSS survey were more in the range covered by the point sets.	
12	Provide methods and/or justification for the Q prior in the proposed base model.	The Panel would like a better justification for how the Q prior was obtained.	Catchability is estimated based on a normally distributed prior with a mean of 0 and a standard deviation of 0.1 in the proposed base model (catchability is estimated in log space). The decision to assume a relatively small standard deviation (0.1) was made to prioritize model stability. In the development of the proposed base model, sensitivities run with standard deviation of 0.2 resulted in high estimates of catchability (~0.5; 1.5 in arithmetic space) and low estimates of natural mortality (~0.4yr <sup>-1</sup> ). The estimate of log-catchability in the proposed base model is 0.08 (1.08 in arithmetic space), which is consistent with values used / estimated in previous benchmark assessments. The 2014 benchmark assessment fixed log-catchability at 0 (1 in arithmetic space), and the 2017 benchmark assessment estimated log-catchability to be 0.11 (1.12 in arithmetic space).	A
13	Get and plot sardine data for the juvenile rockfish survey, including the index and composition data (if available).	The juvenile rockfish survey may provide information in recruitment not currently in the model.	A figure from the 2017 cruise report shows that there was a spike in 2015 in young of year (YOY – age 0) Pacific sardine but not adult (age 1+) Pacific sardine. See also the response to Request 16, which shows positive recruitment deviations in 2016 and 2017, suggesting that the data from the juvenile rockfish survey may be capable of detecting recent recruitment events. This	

Nr	Request	Rationale	Response	Model(s)
			survey could not be included in the assessment because it has not been subject to a methodology review.	
14	Run a model without the R1 offset and with the R1 offset estimated but with no penalty on this parameter.	The Q profile has a likelihood component for the R1 offset (aka the “SR regime parameter”), but it was never the intention to impose a penalty / prior on this parameter – the STAT and Panel were unclear how this penalty was defined.	Three models were shown: the 2020 proposed base model (“base”), a model that does not estimate the SR regime block parameter (“no sr_regime”), and a model with the SR regime parameter assigned a lambda of 0 in the likelihood (“sr_regime lambda=0”). It was agreed that setting the lambda for the R1 offset to 0 is the best approach because it best matches the intent of how this parameter was to be treated in the 2017-2019 assessments.	A, B1, B2
15	Provide a model run with corrected CCPSS data included into the model.	These data are incorrect in the proposed base model sensitivity.	This will now be addressed in subsequent requests.	
16	Evaluate whether the model without the R1 offset (see request 14) can estimate steepness. If not, conduct a model run with steepness fixed at 0.3.	It is not clear which data are informing the estimate of steepness; the current base model appears to depend much on the R1 offset.	Steepness was not estimable, and the STAT proposed to set steepness at 0.3 (a value consistent with previous estimates). The three figures below show the 1+ biomass time series for 2005-2020 and 2015-2020, and the recruitment deviations. The STAT and Panel agreed that steepness would be fixed at 0.3 in the final base model.	A, C1, C2
17	Examine the sensitivity to removing the spring AT age data.	The spring AT age data are based on a pooled age-length key, which is not appropriate because the estimates of age-frequency will be biased as no account is taken of varying cohort strengths.	The fits to age compositions in which fish were re-aged (2017 and 2018) and 2019 were relatively good. The STAT and Panel agreed that the spring AT age data would be excluded from the final base model.	D
18	Run a model with all accepted changes, i.e.: (1) turn off the likelihood component for the R1 offset parameter by setting the ‘lambda’ to zero, (2) fix steepness to 0.3, and (3) remove the spring AT age data.	These model changes were agreed based on the day 2 requests.	The estimate of the fishing mortality rate for 2020 is unrealistically high and is related to pre-specifying the catches (particularly for MexCal S2) from the 2019-2 model year onwards.	E
19	Remove earlier years of AT age-composition data and/or include these compositions as a separate fleet because they do not appear to be representative of the biomass observed by the acoustics.	The early AT age compositions were not well sampled (based on few clusters) and likely not representative of the population surveyed using the acoustics.	The fits to the data are better, but still have fishing mortality rates that are unrealistically high for 2020-2. This led to the suggestion to use the forecast F option in the forecast for 2020 rather than setting catches after the 2019-1 model year to the observed catches for the 2018-2 and 2019-1 model years. This suggestion formed part of the final base model.	F
20	Conduct a model run that allows for a time change in AT Q in 2015 (Q=1	There is evidence that the proportion of the stock shoreward of the acoustic trawl	The results of this run look reasonable. This addresses the nearshore region not surveyed by the acoustic trawl survey.	G

Nr	Request	Rationale	Response	Model(s)
	before 2015 and Q equal to the ratio of the AT estimate of biomass for 2019 [33,632t] to the sum of the CCPSS estimate of biomass for 2019 [12,280t] and the AT estimate of biomass for 2019 [33,632t].	survey area has increased since at least 2015 onwards.		
21	Run a model with all agreed changes to the proposed base model : (a) the changes in request 18, (b) the changes to acoustic Q from request 20, (c) basing removals off Mexico from the 2020-1 model year on the estimates of fishing for the 2018-2 and 2019-1 model years (i.e., the catches for model years 2001-1 and 2020-2 are based on the F's estimated for model years 2019-1 and 2018-2) , and (d) use the selectivity pattern for the AT survey from the proposed base model	This was a possible new base model.	The 2020 catches are now based on F's, and match the F estimated for the 2018-2 and 2019-1 model years. Time series of derived outputs for the model are largely the same as previous model runs. The Panel investigated the impact of the near zero acoustic trawl survey selectivity on the estimated biomass, finding that the near-zero selectivity still amounted to a large enough biomass of age 0 fish in the acoustic estimate, so that the acoustic biomass estimate is quite a bit different than expected from the model 1+ biomass estimate.	H
22	Run the following sensitivities: a. consider a time-invariant dome-shaped selectivity pattern for the AT age data (treated as a separate fleet); b. consider a dome-shaped selectivity pattern for the AT age data (treated as a separate fleet) with the ascending limb time-varying; c. set the 2019 and 2020 Mexican catches to the average of the last N years (TBD by STAT); and d. change the year in which the time change in Q for the AT survey occurs.	These sensitivity analyses reflect some of the major sources of unresolved uncertainty.	Changing the AT selectivity pattern did not improve the fits to the age compositions. A more complex selectivity pattern is needed to fit these data. Changing the year in which Q changes results in a very similar model to the base model. Using the average catches from MexCal S2 from 2016-2018 (8376 mt) as input catches for 2019 and 2020 resulted in a similar model to the base model. The forecast stock biomass was 32,292 mt compared to 28,275 mt from the base model. Model results were not sensitive to changing the year in which Q changes.	H-a, H-b, H-c, H-d1, H-d2
23	Provide a joint likelihood profile across M and Q. Add standard profiles on M, steepness and Q. Also show how	M and Q are likely influencing the poor fits, a joint likelihood profile across M and Q would be helpful.	Likelihood profiles for steepness show that recruitment drives the steepness profile. Likelihood profiles for M show that the data are informative and with little conflict between data sources.	Variant of H with single Q

Nr	Request	Rationale	Response	Model(s)
	derived parameters change across the likelihood surface, e.g., 2020 season 1 biomass and stock depletion, where appropriate.		Likelihood profiles on M for only the age data sources showed that the PNW fleet wants a lower M, while the AT survey age data want a higher M. The likelihood profile for Q, using a single fixed Q, looks fine. The Q profile shows that the acoustic trawl survey wants a high Q value. The joint profile on M and Q, using a single fixed parameter for Q, showed the correlation between these two parameters. The Panel requests the STAT use a contour plot for this profile in the final document and a profile for Q that accounts for the change in Q in 2015.	to enable profiles on Q (but see response)
24	Conduct additional sensitivity tests in which: e. the AT age data are down-weighted by 50%, f. the PNW age data are down-weighted by 50%, g. the AT age data are restricted to 2017 onwards, and h. an additional variance parameter is estimated for the AT survey.	The Panel wished to explore the sensitivity of the results of the weighting of the data.	The time-trajectories of biomass (both long-term and recent) are robust to these changes. The estimate additional variance for the AT survey is 0.22.	H-e, H-f, H-g, H-h
The STAT and Panel agreed that model H would be the final base model.				

Table A4.2. Summary of the models requested of the STAT during the review. For model B1 to H, only changes compared to proposed base model A are indicated. The final base model is H (final column).

	ALT (2017-2019)	A: 2020 Proposed Base	B1	B2	C1	C2	D	E	F	G	H
Time Period	2005-2018	2005-2019									
Fisheries (number, type)	3, commercial	3, commercial									
Surveys (number, type)	1, AT	1, AT									
Natural Mortality (M)	Fixed (0.6)	Estimated (prior)									
Growth	Fixed (WAA)	Fixed (WAA)									
Spawner-recruit relationship	Beverton-Holt	Beverton-Holt									
Equilibrium recruitment (R0)	Estimated	Estimated									
Steepness (h)	Estimated	Fixed (0.27)			Estimated	Fixed (0.3)		Fixed (0.3)	Fixed (0.3)	Fixed (0.3)	Fixed (0.3)
Tot. Recruitment Variability (sigmaR)	Fixed (0.75)	Fixed (1.2)									
Init. Equilibrium recruitment offset	Estimated	Estimated (now called SR regime)	Not estimated	Estimated, but $\lambda=0$	Estimated, but $\lambda=0$	Estimated, but $\lambda=0$		Estimated, but $\lambda=0$	Estimated, but $\lambda=0$	Estimated, but $\lambda=0$ Q=1, <2015 else Q=0.733	Estimated, but $\lambda=0$ Q=1, <2015 else Q=0.733
Catchability (q)	Estimated	Estimated (prior)									
Selectivity (age-based)	Dome-shaped and asymptotic	Random walk and asymptotic									
Fishery selectivity											
Age composition	Yes	Yes									
Form	Age-specific, random walk (MexCal) / Logistic (PNW)	Age-specific, random walk (MexCal) / Logistic (PNW)									
Time-varying	No	Yes									
Survey selectivity											
Age composition	Yes	Yes					omit spring age comps	omit spring age comps	Only keep 2017-19 summer age comps	omit spring age comps	omit spring age comps
Form	Age-specific, asymptotic	Age-specific, asymptotic									
Time-varying	No	Yes (age-0)									
Fishery selectivity	Random walk (option 17)	Random walk (option 17)									



	ALT (2017-2019)	A: 2020 Proposed Base	B1	B2	C1	C2	D	E	F	G	H
Catches for seasons with no catch data	=preceding 2 seasons' catch data	=preceding 2 seasons' catch data									=preceding 2 seasons' F
Data Weighting	No	No									
Convergence	Yes	Yes			No						

#### *Additional Sensitivity Runs:*

H-a: same as H, but with time-invariant dome-shaped selectivity pattern for the AT age data (treated as a separate fleet)

H-b: same as H, but with a dome-shaped selectivity pattern for the AT age data (treated as a separate fleet) with the ascending limb time-varying

H-c: same as H, but with the 2019 and 2020 Mexican catches set to the average of the last 3 years (MexCal S2, 2016-2018)

H-d1, H-d2: same as H, but changing the year in which the time change in Q for the AT survey occurs (both earlier and later)

#### *Sensitivity on weighting:*

H-e: same as H, but with the AT age data are down-weighted by 50%

H-f: same as H, but with the PNW age data are down-weighted by 50%

H-g: same as H, but with the AT age data are restricted to 2017 onwards (as for model F)

H-h: same as H, but with an additional variance parameter estimated for the AT survey

#### *Sensitivity runs included in the presentation “Assessment of the Pacific Sardine Resource in 2020”*

Additional sensitivity runs were included in the presentation given by Peter Kuriyama (see e.g., Figure 2, but also sensitivity runs considering recruitment autocorrelation, more flexibility to the AT survey selectivity, down-weighting survey age comps, alternative CAGEAN-like recruitment, and combinations of these), but these included estimation of the “SR regime” parameter without setting  $\lambda=0$  (see Figure 3), so their results were not wholly reliable and were only briefly covered during the meeting; these (apart from Figure 2) are not shown here for this reason.

## Annex 5: Final base model (model H in Annex 4)

The final base model incorporates the following specifications (from STAR Panel report):

- sexes were combined; ages 0-10+;
- two fisheries (MexCal and PacNW fleets), with an annual selectivity pattern for the PNW fleet and seasonal selectivity patterns (S1 and S2) for the MexCal fleet;
  - MexCal fleets: age-based selectivity (time-varying and non-parametric [option 17 in Stock Synthesis]);
  - PNW fleet: asymptotic age-based selectivity (time-varying for the inflection point);
  - age-compositions with effective sample sizes calculated by dividing the number of fish sampled by 25 (externally) and lambda weighting=1 (internally);
- Beverton-Holt stock-recruitment relationship with “steepness” set to 0.3;
- initial equilibrium (“SR regime” parameter) estimated with the ‘lambda’ for this parameter set to zero;
- $M$  estimated with a prior;
- recruitment deviations estimated from 2005-2020;
- virgin recruitment estimated, and  $\sigma_R$  fixed at 1.2;
- initial  $F$  estimated for the MexCal S1 fleet and assumed to be 0 for the other fleets;
- fishing mortality for the 2020-1 to 2020-2 model years set to those for the 2018-2 and 2019-1 model years.
- AT survey biomass 2006-2019, partitioned into two (spring and summer) surveys, with  $Q$  set to 1 for 2005-2014 and 0.733 for 2015-2019;
  - age-compositions with effective sample sizes set to 1 per cluster (externally);
  - age-compositions for the spring AT survey ignored;
  - selectivity is assumed to be uniform (fully-selected) above age 1 and estimated annually for age-0.